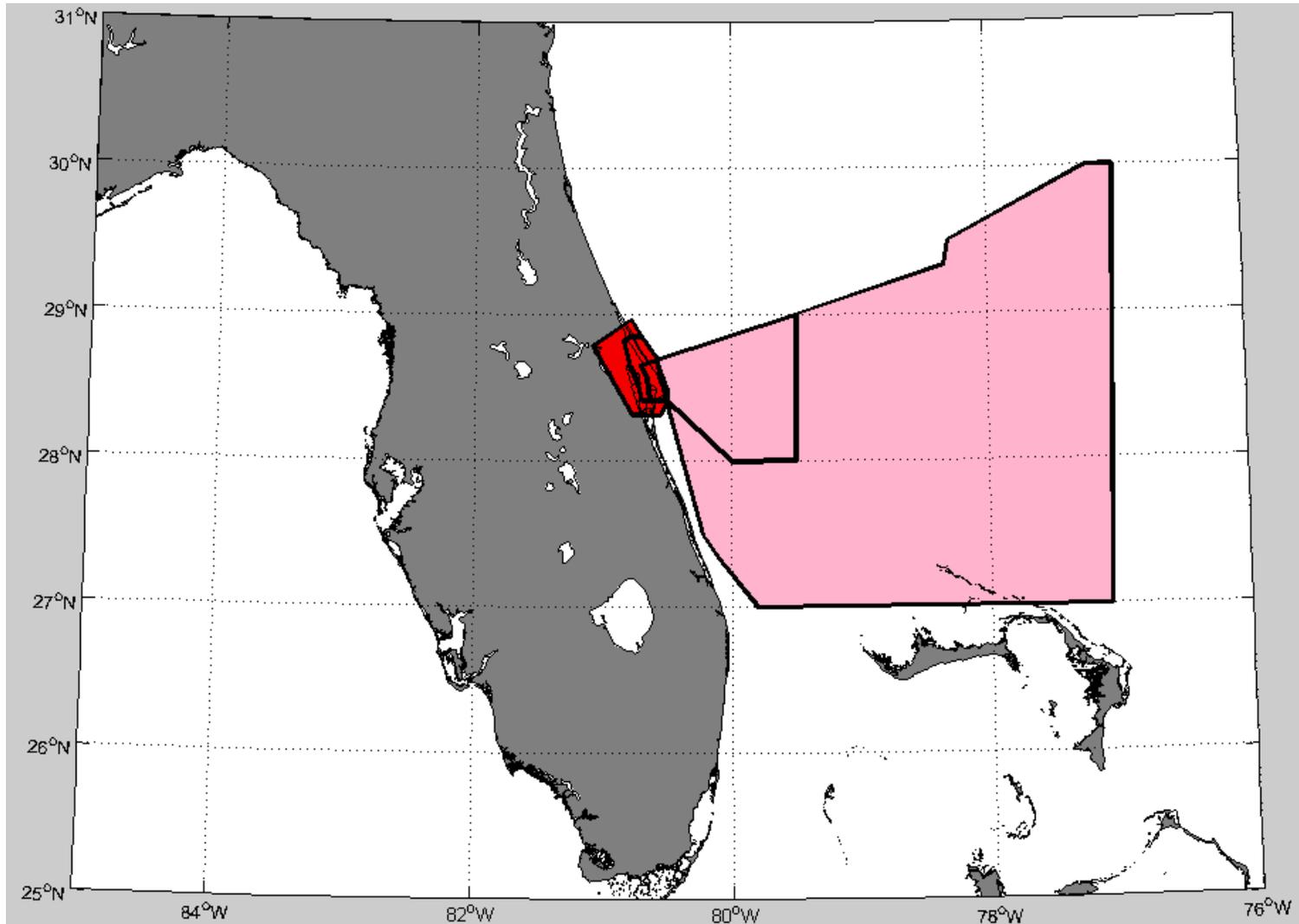

An Analytical Model of the Impacts of Airspace Restriction

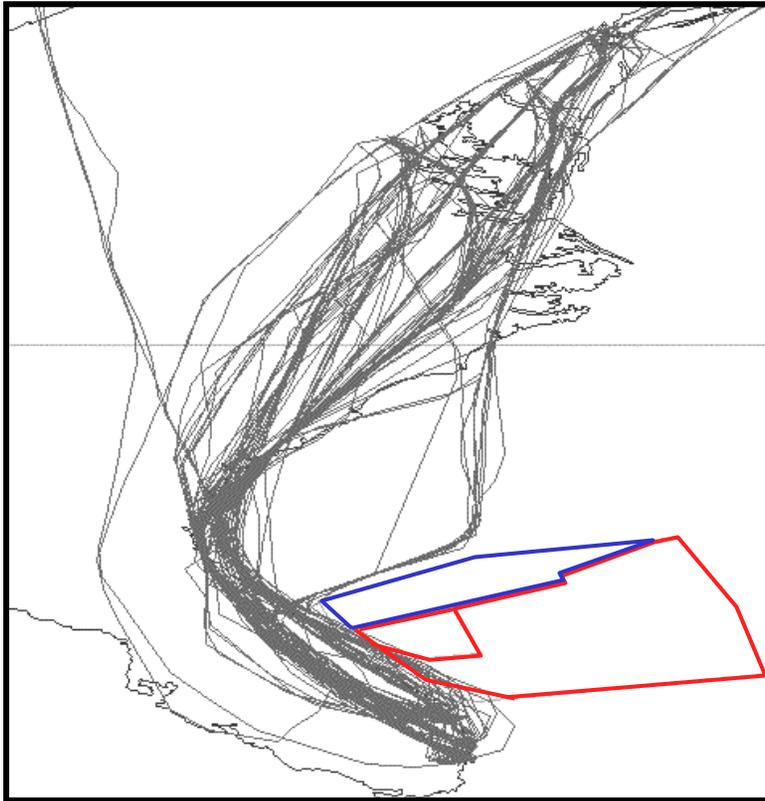
John M. Falker
James K. Kuchar

International Center for Air Transportation
Massachusetts Institute of Technology

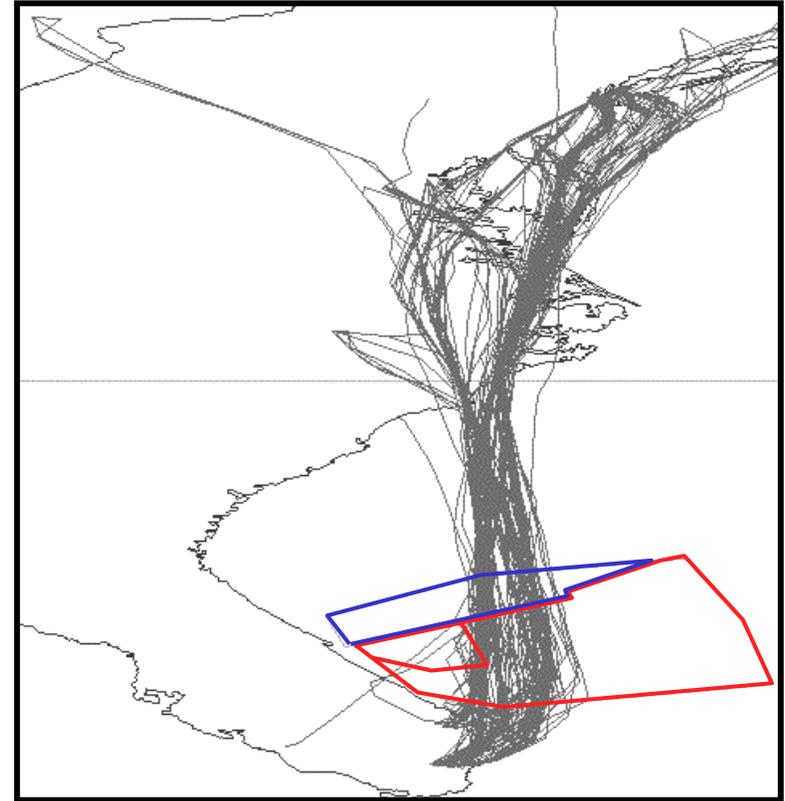
Special Use Airspace



“Special” vs. “Normal” Use

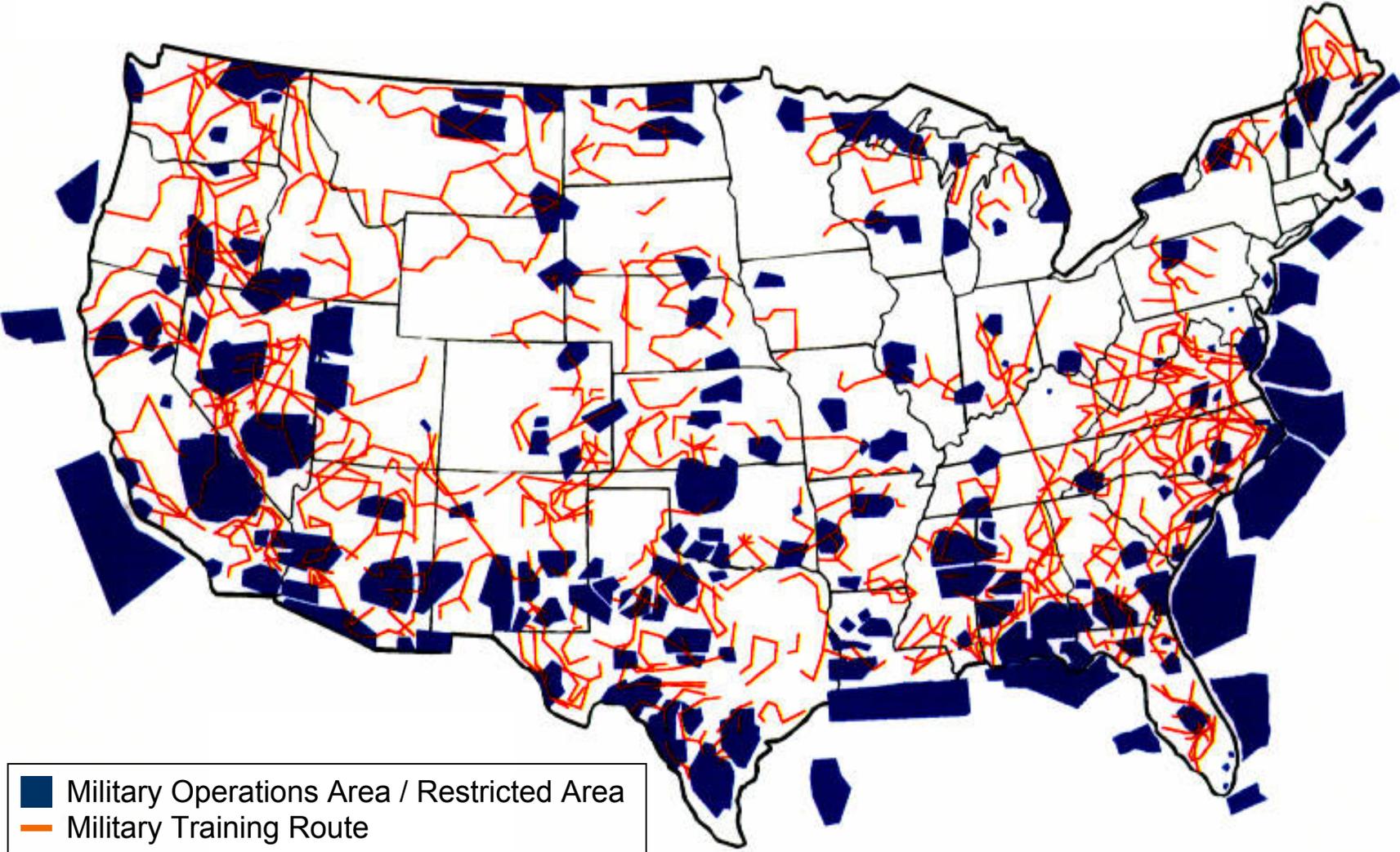


SUA Active
traffic diverted around



SUA Inactive
traffic allowed through

Military Airspace > 1,000,000 mi²



Abstraction of Impacts

$$\text{Total Annual Impact Cost} \approx N \cdot E \cdot D \cdot C$$

- N = # conflicts per SUA event ← *Focus*
- E = # SUA events per year
- D = units of impact per conflict
- C = cost per unit of impact

Modeling Approaches

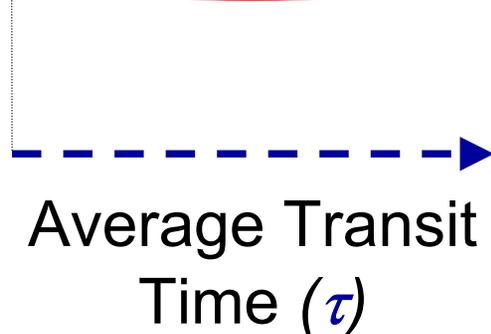
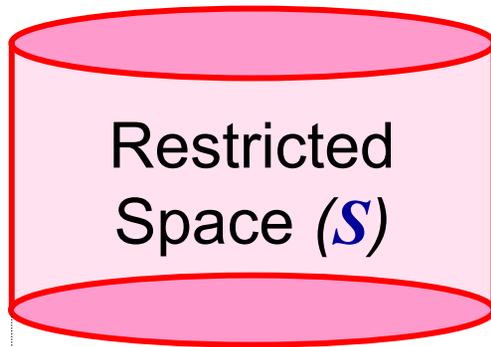
- **Empirical Models**
 - Total Airspace and Airport Modeler (TAAM)
 - Future ATM Concepts Evaluation Tool (FACET)
 - Collaborative Routing Coordination Tools (CRCT)
 - Detailed Policy Assessment Tool (DPAT)
 - Airspace Occupancy Model (AOM)
- **Analytical Models**
 - Gas Model

MIT Analytical Conflict Model

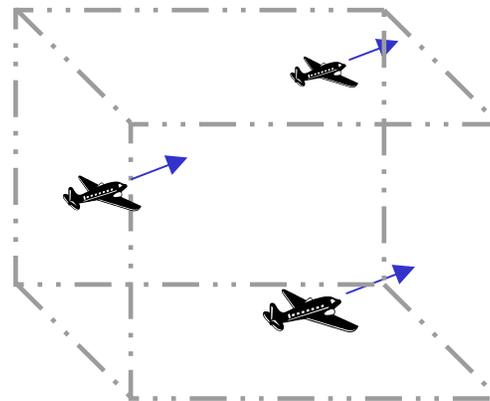
Average space-time conflicts represented by this function of 4 variables:

→

$$N = S \cdot \rho \cdot \left(1 + \frac{T}{\tau} \right)$$



Average Traffic Density (ρ)



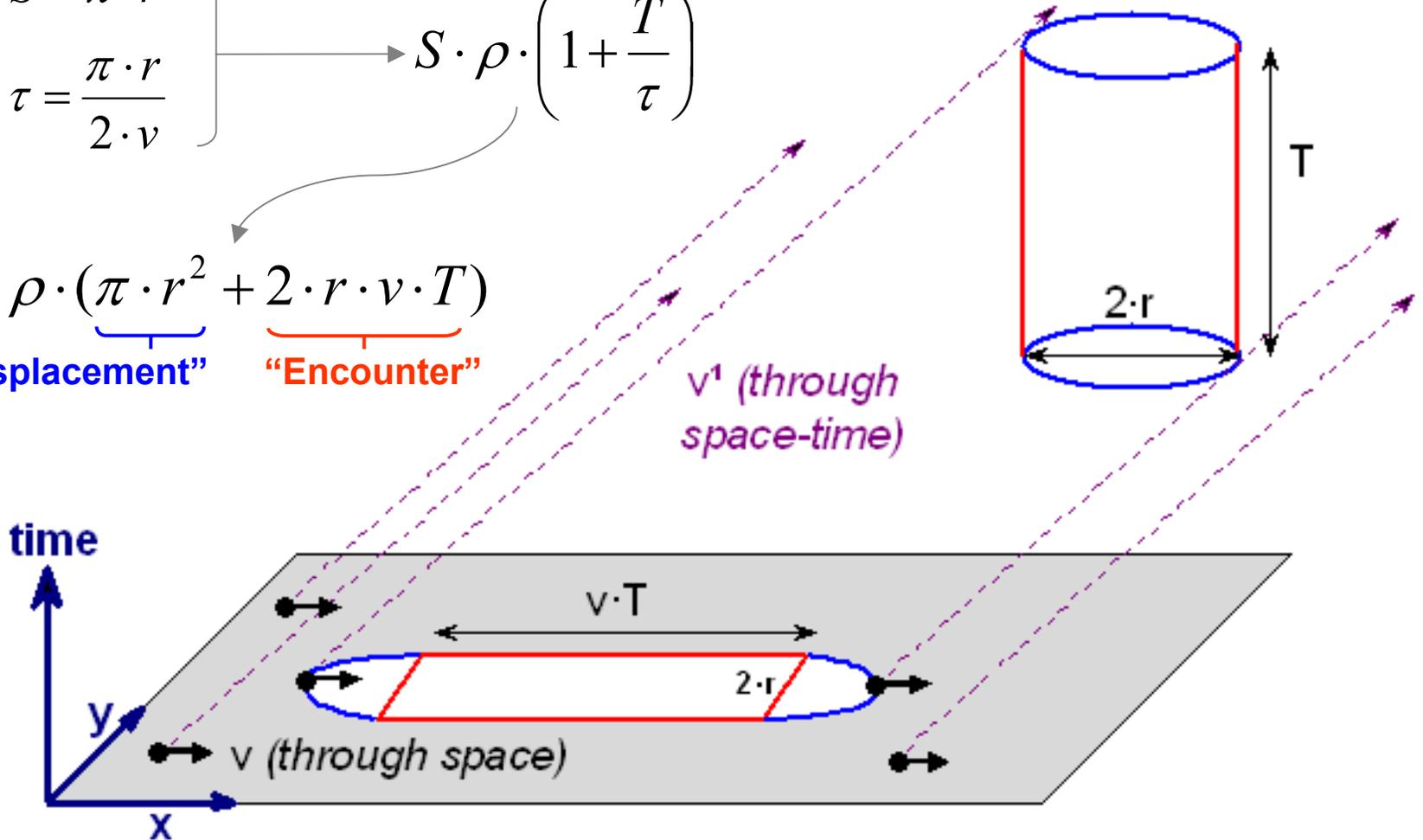
Restricted Time (T)



Example: 2-D Traffic, Circular SUA

$$\left. \begin{aligned} S &= \pi \cdot r^2 \\ \tau &= \frac{\pi \cdot r}{2 \cdot v} \end{aligned} \right\} \rightarrow S \cdot \rho \cdot \left(1 + \frac{T}{\tau} \right)$$

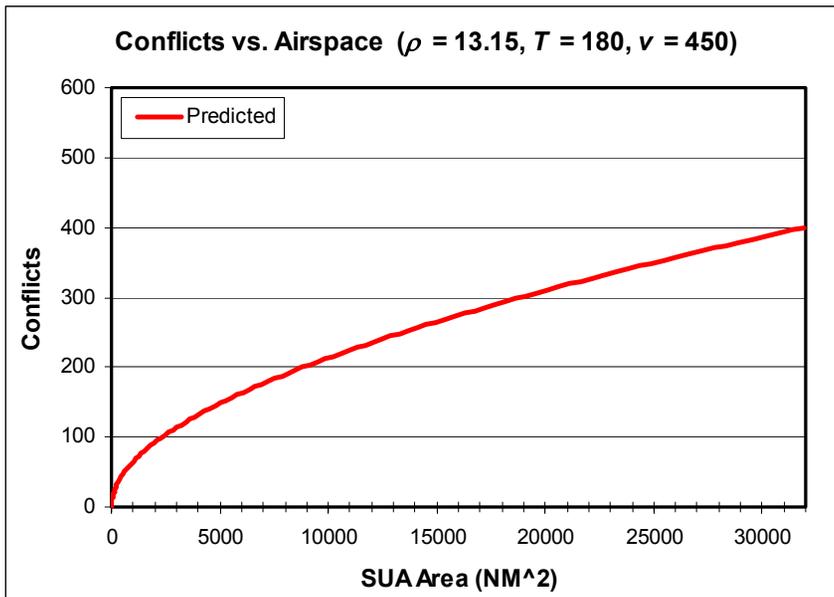
$$\Rightarrow \rho \cdot \underbrace{(\pi \cdot r^2)}_{\text{"Displacement"}} + \underbrace{2 \cdot r \cdot v \cdot T}_{\text{"Encounter"}}$$



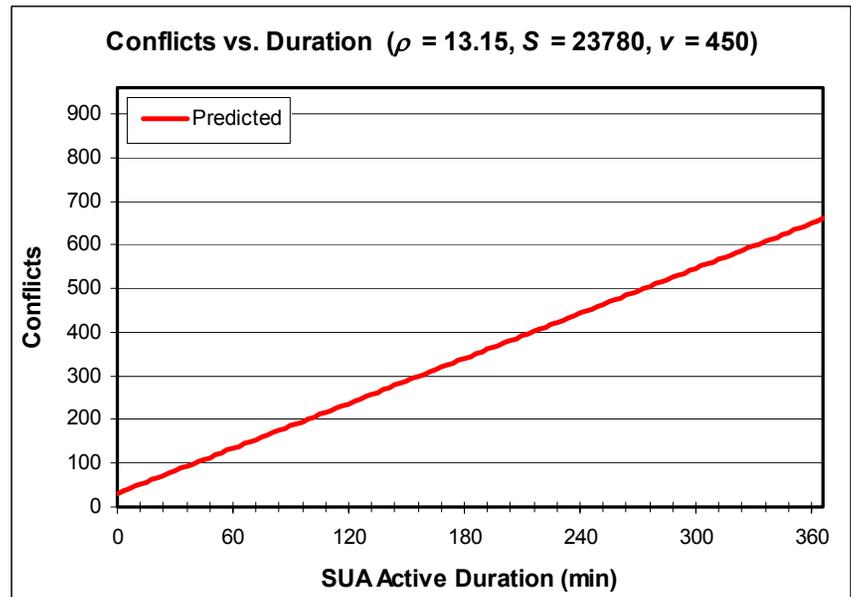
Predicting Conflicts

- Applied analytical model to predict conflicts
- Investigated sensitivity of each parameter in model, over broad ranges

Varying S



Varying T



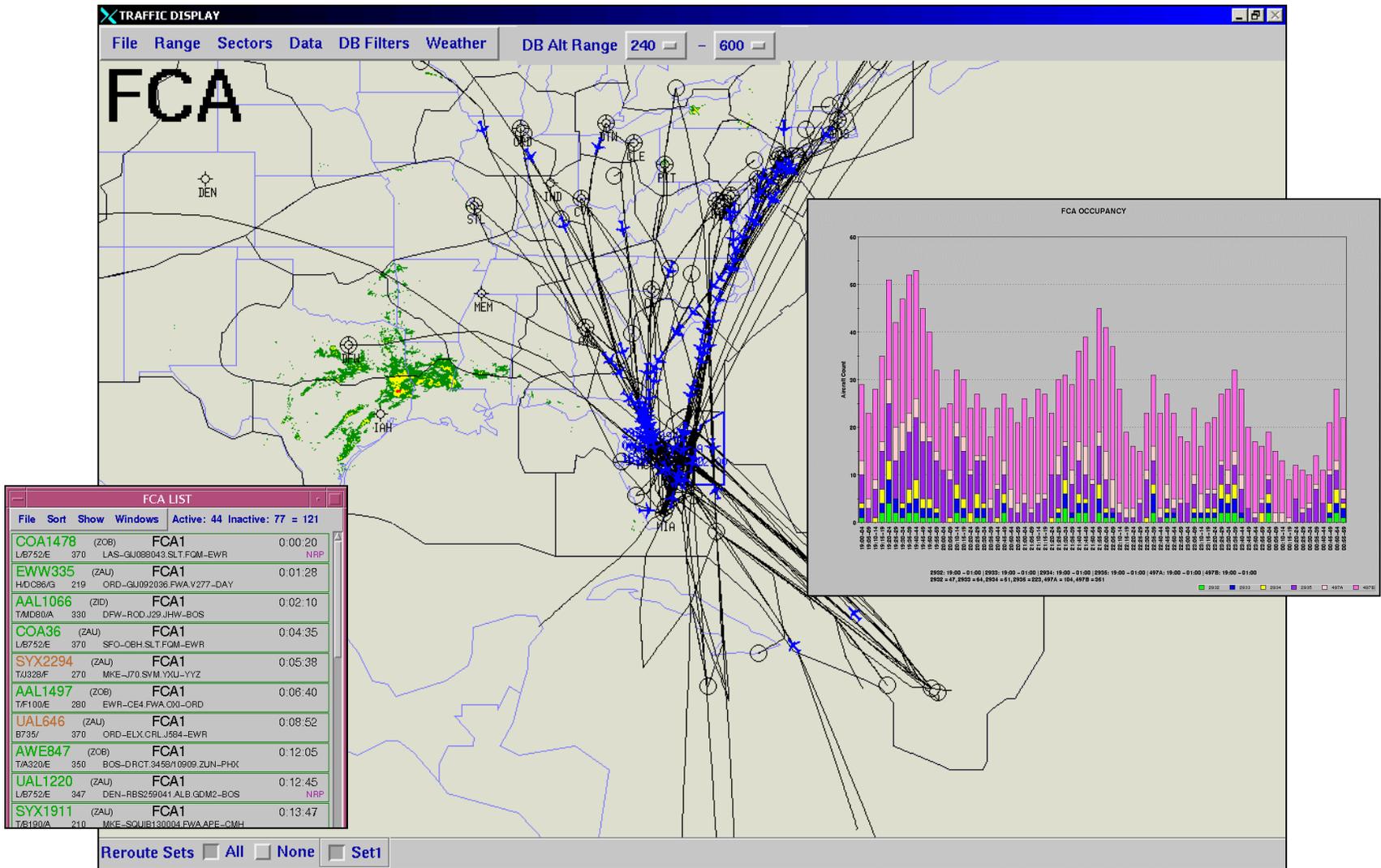
Empirical Data

- Actual ETMS tracking data
 - Miami Center (ZMA), commercial traffic only
 - 1 week: March 14 - 21, 2001
- Analyzed temporal variations in traffic density
 - High: $\rho_{day} \approx 13.15$ a.c. per 10,000 NM² (1100-1700 local)
 - Low: $\rho_{night} \approx 1.09$ a.c. per 10,000 NM² (0100-0500 local)
- Empirical model (CRCT) used to count conflicts that “would have occurred” if SUA active

* Access to ETMS data and CRCT courtesy of MITRE/CAASD

MITRE CRCT

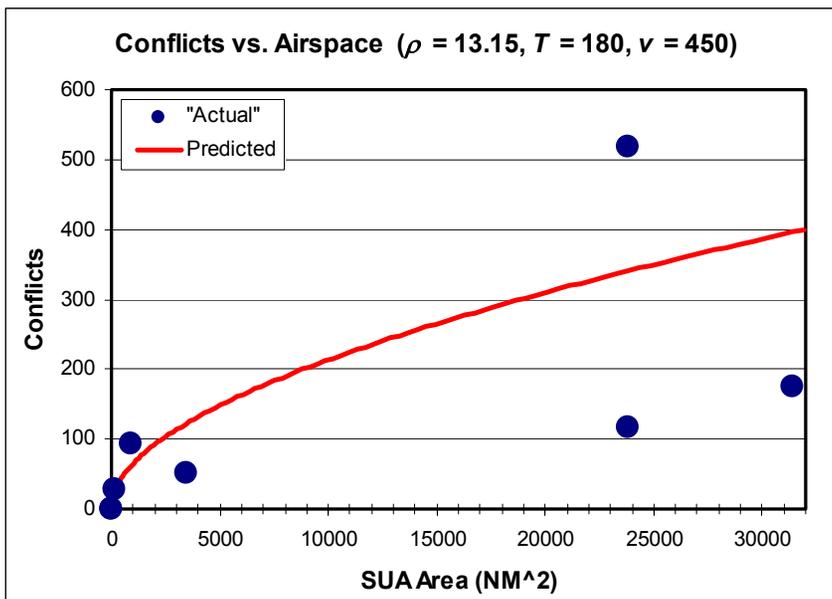
Collaborative Routing Coordination Tools



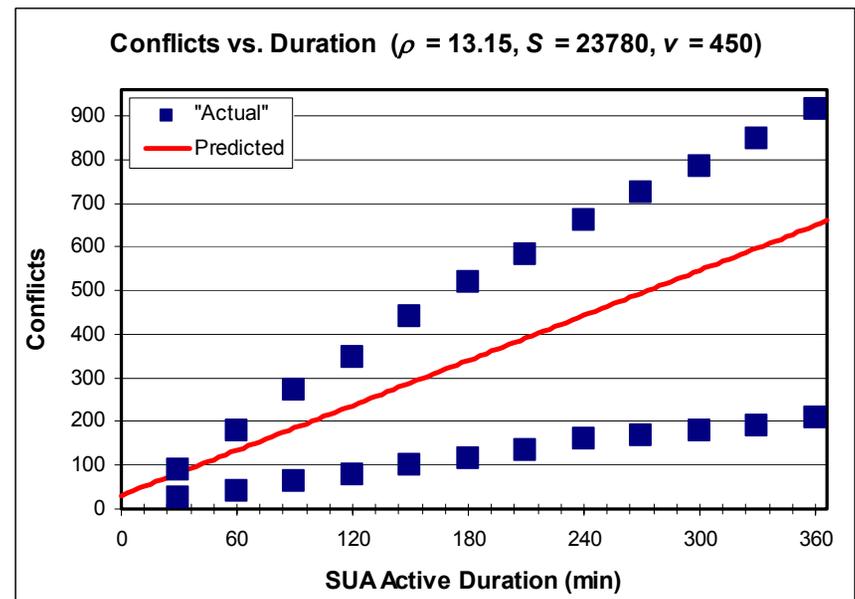
Empirical Validation??

- Compared predictions with CRCT “actual” counts
- Observations diverged from predictions
 - Plots suggested two different sets of data

Varying S



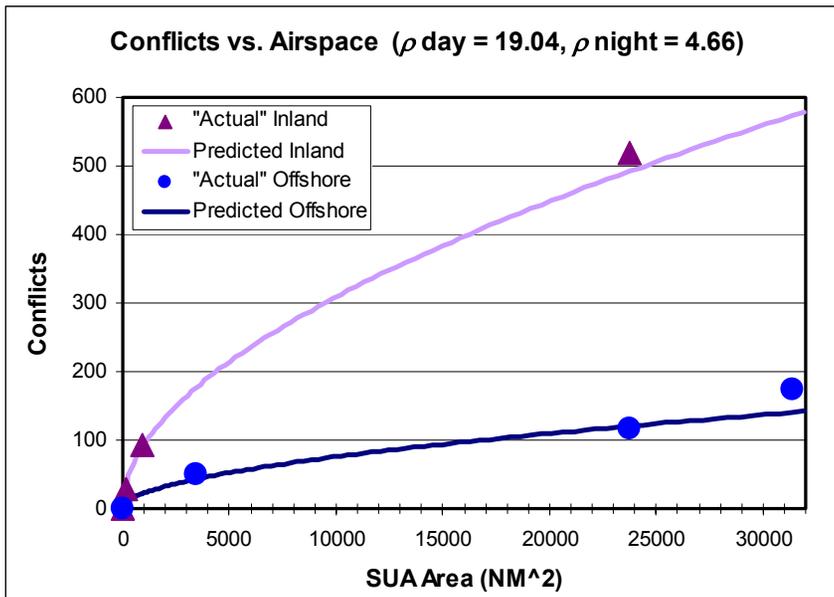
Varying T



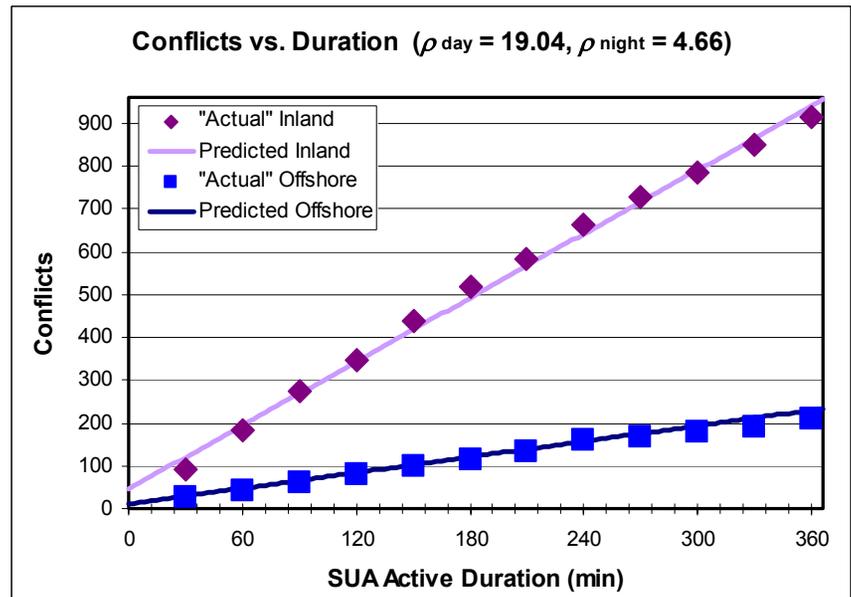
Empirical Validation

- Corrected for traffic density inland vs. offshore
- Then observations did support predictions
 - All within 99% confidence limits

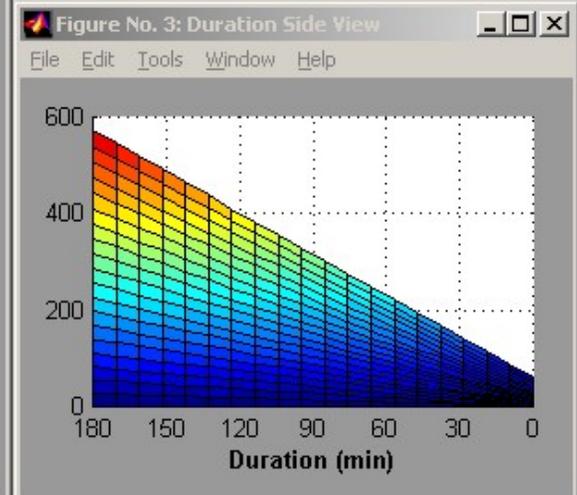
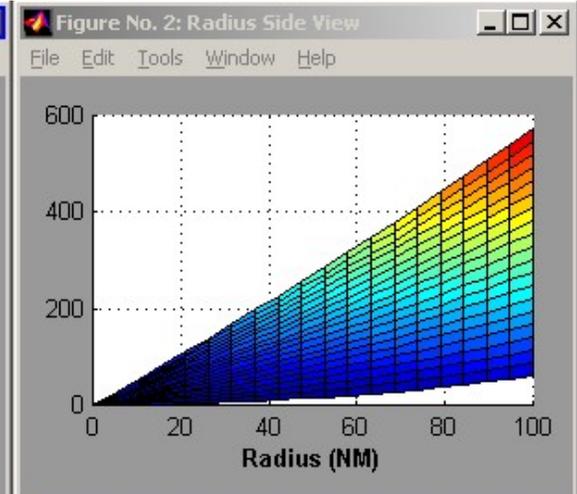
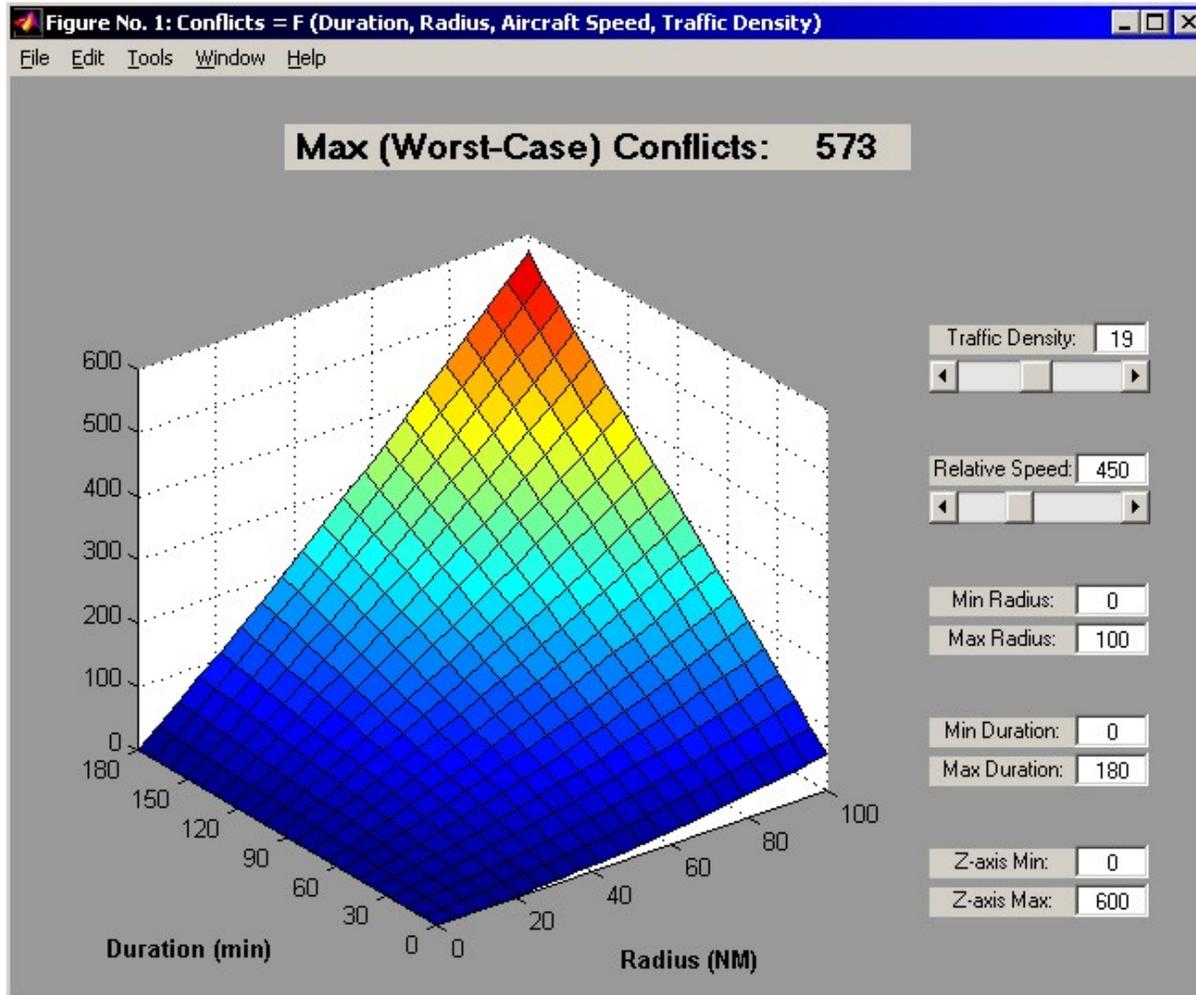
Varying S



Varying T



Sensitivity Analysis



Future Work

- **Exploratory Analysis**
 - **Air/space traffic management**
 - SUA size, duration, location
 - Tactical conflict detection/resolution
 - **Air transportation developments**
 - Growth, ATC procedures, CNS technologies
 - **Space transportation developments**
 - New vehicles/operations, changes in demand
- **Estimated Impact Costs** $\approx N \cdot E \cdot D \cdot C$
- **Recommendations**